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CONTENTS:

Report of Sanitary Chemical Water Analyses, . . *Edward Bartow.*

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KANSAS UNIVERSITY SCIENCE BULLETIN.

VOL. I, No. 4. APRIL, 1902. { WHOLE SERIES VOL. XI, No. 4.

REPORT OF SANITARY CHEMICAL WATER ANALYSES.

BY EDWARD BARTOW.

IN the spring of 1898, there was begun at the University a series of systematic analyses of the waters of the rivers, wells and water-supplies of the state. The work has been carried on with more or less continuity till the close of the school year in June, 1900. At that time, owing to the removal of the department of chemistry to the new building, and the fact that the rooms set apart for such work could not be equipped, it was necessary to stop the work. It is hoped, however, that we will soon be able to take it up again.

The results set forth in this article have been obtained by the help of several of the students. The first analyses* were made by C. E. McKinnie, Ph. C., 1898, and G. M. Smith, Ph. C., 1898. The analyses were continued by D. F. McFarland, B. A., 1900, W. J. Rothrock, B. A., 1900, B. C. Winslow, B. A., 1899, E. A. Sweet, Ph. C., 1900, and F. W. Fogwell, Ph. C., 1900.

As far as possible, each student has made a specialty of some problem, at the same time carrying on the work in such a way as to give a systematic comparison of all the work. There have thus been made comparative analyses of the water of the Kansas river at Lawrence at different seasons, and at different stages of the river. There are comparative analyses of the river water, filtered and unfiltered; comparative analyses of the river water, above and below the city, at the middle of the river, and along the bank. There are analyses of well-waters from city wells and from wells in the country near Lawrence; analyses of water from wells suspected of contamination, and of

* Proceedings of the Kansas Pharmaceutical Association, 1898, page 53.

those which were supposed to be all right. There were but few analyses of waters away from Lawrence, owing to the difficulty of obtaining samples. Through the kindness of Prof. E. C. Murphy, a number of samples were obtained from the Neosho, the Verdigris, and the Marais des Cygnes. The comparison of these with the waters of the Kansas is quite interesting. It would be still more interesting, however, if the analyses of the river waters could be made more frequently, and at different stages of the rivers.

The methods of analysis are those in use in the laboratory of the state board of health of Massachusetts. Analyses have usually been made on the day following the date of collection, or within twenty-four hours from the time the water was obtained. The records are given in parts per million, according to the recommendation of the American Chemical Society.

We realize that the work has been merely begun, and that but little has been done, due partly to the lack of a well-equipped water-analysis laboratory, and partly to the fact that the students who assisted in the work were carrying on the regular university courses at the same time. Nearly 250 analyses have been made, the reports of which are arranged in the twelve tables of this report.

TABLE I.—Analyses of the water from the Kansas river, collected about 100 feet above the dam at Lawrence. (Parts per 1,000,000.)

Number.	Date of collection.	Gauge.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
			Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1898.														
1	Feb. 4	0.0	Slight.	Slight.	0.0	644	42	602	114	.019	.094	.334	.000	.....	.....
3	" 11	1.1	V. D.	V. H.	0.0	736	204	532	86	.171	.612	.208	Trace.	.....	.....
5	" 18	1.4	"	"	0.0	1,410	.....	.....	41	.400	2.290	1.070	.....	.....	.....
9	" 26	0.8	Slight.	Slight.	0.0	607	.....	.....	69	.253	.930	.450	.....	.....	.....
13	Mar. 5	0.6	"	"	0.0	844	.....	.....	69	.066	.312	.439	.....	.....	.....
17	" 11	0.4	"	"	0.1	574	.....	.....	77	.006	.299	.323	.000	215	.....
22	" 18	0.8	"	"	0.0	566	.....	.....	67	.020	.510	.230	.....	220	.....
24	" 25	0.9	"	Heavy.	0.1	656	.....	.....	58	.036	.700	.638	.....	230	10.8
31	Apr. 1	0.6	"	Slight.	0.0	706	152	554	67	.060	.560	.286	.....	240	5.7
35	" 8	1.0	"	"	0.0	744	176	558	59	.085	.645	.243	.....	230	8.0
45	" 15	1.0	"	"	0.0	446	70	370	56	.039	.596	.379	.000	205	7.4

TABLE I.—*Concluded.*

Number.	Date of collection.	Gauge.	Appearauce.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
			Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
50	" 22	1.8	V. D.	V. H.	0.2	3,080	582	2,498	37	.310	5.990	.150	.002	170	16.0
55	" 29	1.2	.....	.....	0.0	750	198	552	46	.125	.895	.370	.001	210	11.5
59	May 6	2.7	V. D.	V. H.	0.0	2,426	.....	.....	41	.340	4.810	.....	.....	.....	....
65	" 13	1.6	Decided.	Heavy.	0.0	868	208	660	26	.110	1.110	.024	.....	204	10.7
66	" 16	3.9	V. D.	V. H.	0.0	7,348	778	6,570	18	.660	10.290	.....	.....	.....	....
70	" 20	3.1	"	Heavy.	0.0	4,172	458	3,714	14	1.800	3.575	.....	.....	187	46.6
77	Jun. 10	5.2	"	V. H.	0.0	7,132	.....	.....	13	1.000	15.010	.000	.025	.....	79.2
79	" 17	3.7	Decided.	Heavy.	.....	3,248	.....	.....	9	.280	4.720	.181	.005	.....	33.5
83	" 24	2.4	.....	.....	.....	1,058	.....	.....	19	.150	1.280	.....	.....	166	14.1
88	Jul. 1	1.4	.....	.....	.....	618	.....	.....	18	.170	.920	.057	.008	214	4.4
93	" 15	1.0	.....	.....	.....	528	.....	.....	46	.255	1.000	.995	.003	280	2.9
105	Aug. 1	0.5	Slight.	Slight.	.....	536	.....	.....	56	.054	.530	.058	.000	240	1.6
117	" 15	0.2	"	"	.....	642	.....	.....	82	.048	.372	.165	.004	240	3.2
147	1899. May 4	.....	"	Heavy.	.....	740	64	676	80	.020	.490	.648	.000	220	5.7
162	" 17	.....	Heavy.	"	.....	670	280	390	68	.053	.928	.774	.000	240	1.8
181	Dec. 15	0.0	Slight.	Slight.	.....	698	128	570	124	.027	.241	.....	.....	.....	....
191	1900. Apr. 6	0.6	.....	.....	.....	520	200	320	65	.040	.240	.....	.....	278	5.5
203	" 16	0.9	.....	.....	.....	540	260	280	77	.025	.435	.....	.....	270	5.3
212	" 23	2.6	.....	.....	.....	3,736	.....	.....	80	.015	2.280	.....	.....	144	78.0
218	" 30	2.6	.....	.....	.....	2,440	332	2,108	....	.095	4.305	....	.....	126	61.0
225	May 7	1.7	.....	.....	.....	810	128	682	39	.039	1.000	.....	.....	168	21.0
230	" 14	2.2	.....	.....	.....	4,000	240	3,760	32	.070	3.140	.....	.....	146	63.0
235	" 21	2.6	.....	.....	.....	1,438	.....	....	30	.080	5.300	.....	.....	126	42.0

In table I the variation of the constituents with the height of the water is quite striking. When the first analysis was made, February 4, 1898, no water was flowing over the dam. This stage was again reached on August 15 and December 15 of the same year. Analyses made in the interim show the soluble solids, chlorine and hardness to be lower, and insoluble solids to be higher. Nitrogen in all its forms increases with the increase in the height of the water. The variation of the chlorine is especially noticeable. With the gauge at zero, there were 114 parts of chlorine; with the gauge at five feet, there were only 14 parts of chlorine; and the following week, though

the water had gone down, there were only 9 parts of chlorine. As the water recedes the chlorine increases again, reaching 80 in August, when again there is no water flowing over the dam, and 124 in December.

TABLE II.—Analyses of water from the Kansas river, taken about 300 feet below the Lawrence sewers. (Parts per 1,000,000.)

Number.	Date of collection.	Gauge.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
			Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1898.														
2	Feb. 4	0.0	Slight.	Slight.	0.0	672	134	538	114	.160	.224	.377	Trace.	.....	.....
4	" 11	1.1	Decided.	Large.	0.0	882	.....	.....	73	.205	1.290	.573	Trace.	.....	.....
6	" 19	1.4	"	"	0.0	1,578	.....	.....	37	.333	2.810	1.372	.....	.....	.....
10	" 26	0.8	"	"	0.0	678	.....	.....	69	.186	.950	.341	.....	.....	.....
14	Mar. 5	0.6	"	"	0.0	642	.....	.....	65	.072	.474	.434	.....	.....	.....
18	" 11	0.4	Slight.	Slight.	0.1	790	.....	.....	74	.026	.395	.307	.000	210	.....
23	" 18	0.8	"	"	0.0	566	.....	.....	67	.026	.535	.142	.....	225	.....
25	" 25	0.9	"	Decided.	0.1	850	.....	.....	57	.033	1.200	.472	.....	230	13.8
30	Apr. 1	0.6	.....	.....	0.2	604	80	524	68	.085	.511	.349	.....	230	5.8
38	" 8	1.0	Decided.	Heavy.	0.1	756	228	538	59	.081	.634	.243	.....	220	9.2
44	" 15	1.0	Slight.	Slight.	0.1	732	310	422	54	.088	.602	2.562	.000	225	10.7
51	" 22	1.8	Decided.	Decided.	0.2	4,366	634	3,732	35	.500	5.600	.....	.007	170	.....
56	" 29	1.2	.....	.....	0.0	982	334	648	41	.150	1.340	.411	.000	210	15.0
58	May 6	2.7	Decided.	Decided.	0.2	2,752	.....	.....	41	.346	4.034	.....	.....	.....	.....

This series shows the same variation in the constituents with the height of the river as is noted in the analyses made above the dam. Solids, free ammonia, albuminoid ammonia, and oxygen-consuming capacity are higher than above the dam. Nitrites were sometimes present. Chlorine was slightly lower, showing a similar variation noted by Bailey and Franklin* in examination of the water of the river above and below Topeka. The sewage of Lawrence and Topeka is hence lower in chlorine than the water of the Kansas river, fed by rivers rich in chlorine.

*Kan. Univ. Quart. III, 91 (1894.)

TABLE III.—Analyses of water from the Kansas river. Samples collected one and one-half miles above the city of Lawrence. (Parts per 1,000,000.)

Number.	Date of collection.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
		Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1898.													
11	Mar. 5	Slight.	Slight.	0.0	634	.....	.....	70	.080	.480	.461	.....	.....	.....
15	" 11	"	"	0.0	612	.....	.....	76	.013	.375	.291	.....	215	.....
34	Apr. 9	"	"	0.0	818	182	636	59	.104	.656	.....	.000	230	9.8

TABLE IV.—Analyses of water from the Kansas river. Samples taken from the middle of the river at the foot bridge, Lawrence. Collected 320 feet from the south approach. (Parts per 1,000,000.)

Number.	Date of collection.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
		Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1898.													
8	Feb. 26	Slight.	Slight.	0.0	768	.....	.....	69	.200	.800	.494	.....	.....	.....
12	Mar. 5	"	"	0.0	636	.....	.....	69	.066	.384	.439	.....	.....	.....
16	" 11	"	"	0.0	594	.....	.....	77	.013	.355	.316	.000	220	.....
21	" 18	"	"	0.0	564	.....	.....	68	.013	.355	.318	.....	220	.....
32	Apr. 1	"	"	0.1	628	98	530	67	.075	.640	.273	.....	245	6.3
39	" 8	"	Heavy.	0.0	790	176	614	59	.081	.709	.243	.000	225	10.0

The analyses shown in tables III and IV do not show a sufficient variation to form any definite conclusions.

TABLE V.—Analyses of water from the Kansas river, collected about 100 feet above the dam at Lawrence, filtered through paper before making tests. (Parts per 1,000,000.)

Number.	Date of collection.	Gauge.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
			Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1898.														
67	May 16	3.9	.....	.....	.....	360	182	178	18	.775	.....	.....	.....	.....	.....
71	" 20	3.1	Decided.	None.	0.0	282	126	156	14	.....	.....	.....	.....	151	3.6
78	June 10	5.2	None.	"	0.1	268	.....	.....	13	.178	.133	.000	.025	.....	6.2
80	" 17	3.7	Slight.	"	.....	230	.....	.....	9	.104	.287	.326	.005	.....	3.7
84	" 24	2.4	.....	.....	.....	284	.....	.....	19	.126	.260	.....	.....	162	3.1
89	July 1	1.4	.....	.....	.....	392	.....	.....	18	.099	.245	.322	.008	220	2.4
94	" 15	1.0	.....	.....	.....	456	.....	.....	45	.020	.500	.395	.003	250	1.9
106	Aug. 1	0.5	.....	.....	.....	490	.....	.....	56	.053	.240	.007	.000	120	1.3
118	" 15	0.0	.....	.....	.....	508	.....	.....	82	.042	.239	.006	.004	120	2.5
	1900.														
192	Apr. 6	0.6	Slight.	.....	.....	520	200	320	65	.036	.240	.....	.000	.....	3.0
204	" 16	0.9	.....	.....	.....	490	148	342	74	.040	.265	.....	.....	.....	3.8
213	" 23	2.6	.....	.....	.....	578	164	414	68	.520	1.160	.....	.....	144	7.4
219	" 30	2.6	.....	.....	.....	376	100	276	23	.320	.555	.....	.....	126	6.1
226	May 7	1.7	.....	.....	.....	496	132	364	39	.370	.181	.....	.007	160	4.7
231	" 14	2.2	.....	.....	.....	.....	.....	.....	32	.....	.340	.....	.....	146	4.8
236	" 21	2 6	.....	.....	.....	.....	.....	.....	30	.....	.355	.....	.....	126	5.0

These analyses were made on dates corresponding to those of table I. It will be noted that the same variations occur as in the unfiltered water, but the solids do not show such a wide range. It is easy to find the amount held in suspension, if the solids in the filtered water be subtracted from the amount in the unfiltered. The decrease in the amount of oxygen consumed and in the amount of nitrogenous constituents shows that a large amount of the nitrogen is in the suspended matter.

TABLE VI.—Analyses of water from wells of the city of Lawrence. (Parts per 1,000,000.)

Number.	Date of collection.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
		Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Fixed.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1898.													
36	Apr. 8	None.	None.	0.0	1,092	562	526	104	.015	.126	7.893	.....	250	1.15
37	" 8	"	"	0.0	664	408	256	60	.020	.075	5.250	.....	305	1.30
40	" 15	"	"	0.0	788	518	270	66	.015	.074	7.890	.000	290	2.10
41	" 15	"	"	0.0	552	324	228	36	.010	.056	3.280	.000	230	.95
42	" 15	"	Slight.	0.0	908	310	598	85	.040	.145	1.120	.000	375	2.75
43	" 15	"	None.	0.0	856	442	414	100	.049	.103	6.700	.000	305	1.50
46	" 22	"	Slight.	0.0	752	388	364	74	.013	.126	5.259	.000	250	1.65
86	June 25	.....	.....	.....	1,678	.....	.....	160	.019	.112	10.522	.190	434	1.58
102	July 22	.....	.....	.....	324	.....	.....	10	.028	.115	.306	.001	95	.40
91	" 2	.....	.....	.....	.....	.....	.....	153	.....	.....	8.211	.240	.....	.....
114	Aug. 8	.....	.....	.....	2,408	.....	.....	236	.200	.158	3.952	.010	90	1.00
	1899.													
133	Apr. 21	None.	None.	0.0	808	198	610	150	.034	.083	.....	.001	250	.55
134	" 21	"	"	0.0	228	1,250	1,030	120	.075	.217	.....	.000	480	1.50
135	" 21	"	"	0.0	1,060	.....	.....	83	.044	.116	.164	.....	365	.85
136	" 28	"	"	0.0	490	132	368	20	.006	.170	.323	.001	180	2.00
137	" 28	"	"	0.0	1,322	614	708	44	.015	.116	.132	.000	320	1.50
139	" 28	"	"	0.1	1,460	570	890	164	.110	.134	2.164	.205	410	1.00
140	" 29	"	"	0.0	3,198	.....	.....	400	.080	.385	.000	.000	240	1.60
141	" 29	"	"	0.0	660	.....	.....	80	.145	.060	.....	.000	110	.50
142	" 28	"	"	0.0	1,550	780	770	260	.023	.130	.....	.000	200	.75
143	" 29	"	"	0.0	1,220	.....	.....	36	.030	.140	.....	.000	150	1.00
144	May 5	"	"	0.0	440	140	300	52	.018	.162	1.634	.000	260	.75
145	" 5	"	"	0.0	1,000	320	680	108	.010	.086	2.050	.000	380	.75
146	" 5	"	"	0.0	1,100	100	1,000	160	.220	.123	2.701	.000	240	.70
148	" 5	"	"	0.0	1,140	200	940	166	.090	.230	2.396	.000	110	1.00
152	" 10	Slight.	"	0.0	664	.....	.....	78	.015	.071	.000	.001	260	1.80
153	" 10	"	Slight.	0.0	396	.....	.....	92	.020	.295	.178	.001	370	1.60
154	" 11	"	"	0.0	1,052	.....	.....	116	.028	.140	.203	.000	290	1.10
157	" 13	None.	None.	0.0	750	260	490	36	.043	.149	1.611	.000	250	1.50
158	" 13	"	"	0.0	800	180	620	38	.060	.190	.959	.000	250	1.00
159	" 13	"	"	0.0	910	280	630	42	.030	.170	.387	.001	230	1.00
160	" 17	"	"	0.0	870	220	650	104	.042	.186	.656	.000	390	1.00
168	" 17	"	"	0.0	1,266	266	1,000	372	.023	.240	2.661	.016	370	1.60
182	Dec. 16	.....	.....	.....	.....	.....	.....	72	.015	.038	.....	.....	.....	.....
	1900.													
188	Jan. 26	None.	None.	0.0	.....	.....	.....	60	.011	.043	.....	.000	.....	2.30
189	Feb. 16	"	"	0.0	1,398	338	1,060	90	.448	.281	.....	.000	900	5.60

TABLE VI.—*Concluded.*

Number.	Date of collection.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
		Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Fixed.		Free.	Albuminoid.	Nitrates.	Nitrites.		
194	Apr. 6	"	"	0.0	942	404	538	120	.172	.215	.023	.002	416	1.60
195	" 9	"	"	0.0	634	294	340	56	.002	.011	.163	.000	256	1.40
197	" 10	"	"	0.0	718	248	470	91	.024	.060	.968	.000	264	1.40
198	" 10	"	"	0.0	966	342	624	146	.031	.051	.963	.....	500	1.70
199	" 10	"	"	0.0	1,864	602	1,262	252	.079	.081	1.390	.012	600	2.80
206	" 17	"	"	0.0	1,156	.....	.....	123	.008	.065	1.732	.001	536	1.30
207	" 17	"	"	0.0	708	206	502	80	.010	.042	.815	.001	320	1.50
214	" 24	.....	.....	.....	474	84	390	26	.176	.240	.061	.....	166	.80
221	May 1	.....	.....	.....	368	110	258	41	.014	.081	.077	.....	160	3.60
222	" 1	.....	.....	.....	572	266	316	24	.036	.185	.093	.....	262	2.30
223	" 1	.....	.....	.....	600	354	246	42	.020	.040	.801	.....	331	1.10
232	" 17	.....	.....	.....	1,180	680	500	116	.055	.045	.....	.....	432	2.70

LOCATION OF THE WELLS OF TABLE VI.

36.—933 Vermont street. In house.
37.—1340 Ohio street.
40.—1407 Kentucky street.
41.—Chancellor's residence, Louisiana street; 17 feet deep.
42.—Well at boat-house.
43.—1310 Kentucky street.
46.—1144 New Jersey street.
86, 91, and 206.—1335 Vermont street. Suspected contamination.
102.—Well of A. E. Tweed, East Lee street; 22 feet deep.
114.—925 Connecticut street; 25 feet deep.
133.—Well north of M. E. church.
134.—920 Vermont street.
135.—1113 Rhode Island street.
136.—Well at Quaker church.
137.—1344 Luisiana street.
139.—1339 Kentucky street.
140.—1132 New York street; 24 feet deep.
141.—1203 Rhode Island street; 41 feet deep.
142.—1025 New Jersey street; 42 feet deep.
143.—1345 Vermont street; 43 feet deep.
144.—1211 Rhode Island street.
145.—1200 Kentucky street.
146.—1317 Kentucky street.
148.—1043 Quincy street.
152.—185 Locust street, North Lawrence; shallow.
153.—192 Locust street, North Lawrence; 36 feet deep.
154.—1300 Massachusetts street.
157.—Well at barn of B. W. Woodward.
158.—Well at house of B. W. Woodward.
160.—920 Vermont street; 30 feet deep.
163.—920 Massachusetts street; 30 feet deep.
182.—1211 Tennessee street.
188.—1346 Massachusetts street.
189 and 232.—800 Louisiana street.
194.—1202 Tennessee street.
195.—1326 Tennessee street.
197.—1215 Tennessee street.
198.—1214 Tennessee street.
199.—1325 Vermont street; 29 feet deep.
207.—1324 Vermont street; 37 feet deep.
214.—946 Ohio street.
221.—1018 Vermont street.
222.—1633 Vermont street.
223.—1238 Tennessee street.

These analyses show that we cannot rely on the amount of chlorine as an indication of sewage. Wells less than 500 feet apart and of the same elevation, shown to be pure by complete analyses, have a variation of chlorine from 10 to 308 parts per million, the deeper well having the most chlorine.

Wells of the same depth but of different elevation show more chlorine the less the elevation.

TABLE VII.—Analyses of water from wells in the vicinity of Lawrence.
(Parts per 1,000,000.)

Number.	Date of collection.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as —		Hardness.	Oxygen consumed.
		Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1898.													
48	Apr. 22	None.	Slight.	0.0	814	428	386	46	.012	.122	5.990	.000	170	0.50
49	" 22	"	"	0.0	340	302	38	8	.027	.137	3.213	.000	190	1.75
52	" 29	"	None.	0.0	632	200	432	10	.025	.059	1.668	.000	110	7.75
53	" 29	"	"	0.0	2,010	608	1,402	308	.012	.118	22.070	.001	125	2.50
54	" 29	"	"	0.0	574	260	314	10	.004	.111	2.014	.000	335	2.20
63	May 13	"	"	0.0	200	130	70	3	.095	.050	2.027	.025	170	1.50
75	June 10	Decided.	Slight.	0.0	368	.....	.....	31	.063	.068	.362	.025	.....	.....
81	" 17	Slight.	"	.....	4,054	.....	.....	1,720	.670	.094	.271	Present	328	3.80
82	" 17	"	"	.....	2,504	.....	.....	880	.690	.071	.....	.....	.....	.96
85	" 24	.....	.....	.....	760	.....	.....	141	.020	.130	9.057	.....	289	.90
87	July 1	.....	.....	.....	1,578	.....	.....	174	.033	.228	20.561	.....	84	.46
95	" 15	.....	.....	.....	864	.....	.....	28	.010	.115	.637	.013	193	.37
96	" 15	.....	.....	.....	2,816	.....	.....	426	.036	.129	26.309	.014	155	7.70
101	" 22	Decided.	Heavy.	.....	608	.....	.....	15	.204	.255	.038	.001	132	2.50
103	" 22	.....	.....	.....	524	.....	.....	26	.019	.084	.280	.000	144	.60
104	" 22	.....	.....	.....	800	.....	.....	30	.063	.510	1.430	.000	140	1.85
109	" 31	Decided.	Heavy.	.....	672	.....	.....	18	.156	.400	.005	.001	180	.40
110	" 31	.....	.....	.....	730	.....	.....	66	.240	.206	.049	.001	72	.90
115	Aug. 14	.....	.....	.....	724	.....	.....	24	.032	.147	5.738	.004	150	.93
116	" 14	.....	.....	.....	596	.....	.....	15	.044	.166	4.905	.000	170	.40
	1900.													
227	May 8	.....	.....	.....	870	300	570	60	.030	.295	.380	.....	376	6.30
228	" 8	.....	.....	.....	368	134	234	10	.027	.630	.348	.....	238	5.90

LOCATION OE THE WELLS OF TABLE VII.

48 and 227.—Well at the residence of D. H. Spencer, one-half mile northwest of the University.
49 and 228.—Well in a pasture three-quarters of a mile northwest of the University.
52.—Well in rear of lot south of the first road south of the University.
53.—Well north of the first road south of the University. Deep well.
54.—Well at farmhouse northeast of Lawrence.
63.—Well northwest of Lawrence, on property of Mrs. Richardson. Depth, fifty-seven feet.
77.—Well on land of J. G. Haskell. Deep well.
81.—Well in the southwest corner of Oak Hill Cemetery. Depth, 130 feet.
82.—Well at farm of Mr. Koehring, east of Oak Hill cemetery, 125 feet deep.
85.—Well on farm of Mr. Smith, south of Oak Hill cemetery, about thirty feet deep.
87.—Well on farm of Mr. Gowan, southwest of Oak Hill cemetery, ninety-five feet deep.
95.—Well on J. Russell's farm, north of Oak Hill cemetery.
96.—Well on farm of Mrs. A. Russell, one mile east of Lawrence, twenty-eight feet deep.
101.—Well of W. Kappis, three miles north of Lawrence, twenty-four feet deep.
103.—Well on farm of A. W. Garvin, four and one-half miles north of Lawrence, forty feet deep.
104.—Well on farm of Phil. Heck, four and one-half miles north of Lawrence, seventy-five feet deep.
109.—Well on farm of L. M. Spray, four miles northwest of Lawrence.
110.—Well on farm of J. Wilson, six miles northwest of Lawrence, twenty-four feet deep.
115.—Well on lot of Mr. Roberts, west of McCook field.
116.—Spring near Mr. Duncan's residence, west of Lawrence.

We noted that the solids in solution and the chlorine were lowest to the west and north of the city, while to the south and east they are much higher and in the deeper wells are very high.

The normal chlorine maps of Massachusetts and Connecticut are so helpful in those states, giving a standard for comparison, that we would like one here. The analyses of these country wells from all sides of Lawrence, together with the city wells, show that such a map of this district would be difficult to make, and, if made, valueless, for chlorine alone cannot be used as a test for contamination.

TABLE VIII.—Analyses of water from the Lawrence Water Company's system. (Parts per 1,000,000.)

Number.	Date of collection.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
		Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1898.													
26	Mar. 26	None.	None.	0.0	564	.....	.....	65	.033	.225	.....	.....	220	.....
33	Apr. 1	.....	.....	.....	562	121	441	66	.069	.125	.447	.....	160	1.52
57	May 6	.....	.....	.....	470	224	246	60	.088	.438	.....	.....	.....	.....
90	July 2	.....	.....	.....	.....	.....	.....	60	.350	.230	.206	.000	140	1.18
111	Aug. 8	Decided.	Heavy.	.....	484	.....	.....	45	.270	.410	.261	.....	125	3.30
112	" 8	.....	.....	.....	476	.....	.....	45	.460	.332	.031	.....	125	2.45
113	" 8	Decided.	Heavy.	.....	508	.....	.....	45	.515	.291	.136	.....	125	3.00
	1900.													
186	Jan. 15	.....	.....	.....	598	142	456	62	.262	.074	.278	.000	245	2.20
190	Feb. 17	None.	None.	0.0	.....	.....	.....	....	.060	.135	.....	.....	.....	.....
193	Apr. 6	.....	.....	.....	700	300	400	79	1.021	.160	.....	.....	303	4.00
196	" 9	None.	None.	0.0	610	106	494	81	.225	.262	.....	.....	302	4.34
200	" 12	"	"	0.0	626	120	506	82	1.710	.138	.....	.....	284	3.23
201	" 12	Slight.	Slight.	0.0	642	.....	.....	80	.960	.336	.....	.....	284	.....
202	" 12	"	.....	0.0	620	220	400	82	.850	.316	.....	.....	274	.....
205	" 16	"	Slight.	0.0	600	242	358	80	.105	.130	.....	.....	268	2.85
209	" 19	.....	.....	.....	684	154	530	80	1.570	.155	.....	.....	298	3.41
210	" 19	.....	.....	.....	602	230	372	80	1.000	.347	.....	.....	295	3.90
211	" 19	.....	.....	.....	608	234	374	80	1.000	.265	.....	.....	.....	4.35
215	" 26	.....	.....	.....	656	144	512	84	1.910	.252	.....	.....	295	3.90
216	" 26	.....	.....	.....	656	212	444	82	.490	1.850	.....	.....	300	1.40
217	" 26	.....	.....	.....	576	110	466	81	.060	.404	.....	.....	280	4.43
220	" 30	.....	.....	.....	632	200	432	82	.490	.235	.....	.....	299	2.62
233	May 17	.....	.....	.....	.....	.....	.....	86	.720	.210	.....	.....	270	3.30
234	" 17	.....	.....	.....	.....	.....	.....	88	.800	.200	.....	.....	270	3.30

The water for analyses 26, 33, 57, 90, 186 and 196 was drawn from a tap at 1344 Ohio street; for 190, 205, and 220, from a tap at the University; for 111, from a tap at the water-works; 112, from a tap at 920 Tennessee street, and 113, from a hydrant at Oak Hill cemetery. These three (111–113) formed a comparative analysis. 193, 200, 209 and 215 were analyses of water from the fountain. The water was clear when first collected, but on standing would become turbid, and a sediment would settle out. 201, 210 and 216 are from the second reservoir, and 202, 211 and 217 are from the third reservoir. Three sets of comparative analyses of the water from the fountain and the second and third reservoirs were made. The most remarkable item noted was the very high free ammonia in the fountain, with the gradual decrease in the reservoirs, and the still further decrease noted in the water from the taps.

Numbers 233 and 234 were comparative analyses, on the same day, of water from different parts of the city.

TABLE IX.—Analyses of water from springs in or near the city of Lawrence. (Parts per 1,000,000.)

Number.	Date of collection.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
		Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1898.													
47	Apr. 22	None.	None.	0.0	330	164	166	28	.008	.087	1.475	.000	240	1.1
116	Aug. 14	.....	.....	.....	596	.....	.....	15	.044	.166	4.905	.000	170	.4
	1899.													
138	Apr. 28	Decided.	Slight.	....	788	260	528	48	.001	.136	.013	.....	260	4.5
156	May 13	None.	None.	0.0	640	200	440	40	.035	.200	1.614	.000	235	1.5

Analyses 47 and 156 are of spring-water from the residence of B. W. Woodward.
116, a spring at Mrs. Duncan's, west of Lawrence.
138, a spring in the 1400 block on Ohio street.

TABLE X.—Analyses of water from deep wells. (Parts per 1000.)

Number.	Date of collection.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
		Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1898.													
76	June 10	.....	.....	.....	.....	.....	.....	21.38	.....	.....	.025	.....	.....	.....
	1899.													
149	May 5	Decided.	Heavy.	0.0	86.84	.....	.....	36.00	.00195	.0009	.0007	.000	.20	.....
170	" 25	None.	None.	0.0	.78	.23	.55	.38	.00004	.0022	.0006	.000	.26	.....
171	" 25	"	"	0.0	.....	.....	.....	.05	.00002	.0002	.0006	.000	.24	.....

Analyses 76 and 149 are from the deep well near the Santa Fe freight station at Lawrence.
Analyses 170 and 171 are from a well at Tonganoxie.

TABLE XI.—Analyses of water from cisterns. (Parts per 1,000,000.)

Number.	Date of collection.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
		Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1899.													
132	Apr. 22	None.	None.	0.0	178	.....	.....	12	.049	.242	.000	.001	60	.45
155	May 11	"	"	0.0	666	.....	.....	24	.120	.200	.041	.000	135	.....
161	" 17	"	"	0.0	480	100	380	34	.158	.518	.446	.005	240	4.50
168	" 27	Slight.	"	Brown	.....	.....	.....	20	8.500	7.300	.....	.000	60	630.00
	1900.													
187	Jan. 26	None.	"	0.2	200	80	120	14	.041	.260	.....	.000	.....	9.44
208	Apr. 18	.....	.....	.....	14	4	9	8	.150	.230	.....	.....	.....	9.64
224	May 7	.....	.....	.....	138	42	96	8	.024	.079	.....	.....	103	1.93

Analyses 132 and 224 are of water from the University cistern; 155 is from 1300 Louisiana street; 161 is from 920 Vermont street; 168 is from 1345 Kentucky street; 187 is from Beal's, north of Warren street; 201 is from 946 Ohio street.

With the exception of the University cistern water, these analyses are of water from cisterns supposed to contain contamination. Number 187 was from a cistern the water from which had been used to wash milk-cans. The milk from these cans is supposed to have aided in spreading typhoid fever to several families in the city.

TABLE XII.—Analyses of water from some of the Kansas rivers. (Parts per 1,000,000.)

Number.	Date of collection.	Appearance.			Residue on evaporation.			Chlorine.	Ammonia.		Nitrogen as—		Hardness.	Oxygen consumed.
		Turbidity.	Sediment.	Color.	Total.	Loss on ignition.	Residue.		Free.	Albuminoid.	Nitrates.	Nitrites.		
	1898.													
27	Mar. 24	None.	None.	0.7	568	324	244	6.5	.160	.279	1.449	.001	155	6.1
29	Apr. 1	"	"	0.0	702	278	424	67.1	.073	.247	.107	.000	185	3.5
64	May 13	Slight.	Heavy.	.....	524	232	292	22.0	.065	.375	.039	.000	225	4.5
68	" 18	.....	.....	.....	874	186	688	2.6	.200	1.570	.598	.000	124	16.8
69	" 18	.....	None.	.....	260	112	148	2.6	.....	.630	.....	.....	124	4.4
72	" 21	Decided.	Heavy.	.....	.....	.....	.....	2.8	.130	3.870	.546	.005	160	8.7
74	" 20	"	"	.....	.....	.....	.....	0.5	.110	3.040	.486	.002	134	7.4
	1899.													
173	Oct. 27	"	Slight.	0.0	.....	.....	.....	.....	.254	.336	.734	.000	252	.....

27, 68 and 69 are from the Neosho river, at Iola, collected by Prof. E. C. Murphy.
69 is 68 filtered through paper.
29 and 64 are from the Solomon, at Beloit, collected by Mr. A. D. Rodgers.
72 is from the Marais des Cygnes, at Ottawa, collected by Prof. E. C. Murphy.
74 is from the Verdigris, at Liberty, collected by Prof. E. C. Murphy.
173 is from the Neosho, at Iola, collected by Mr. C. G. Waite.

It is interesting to note the small amount of chlorine in the southern part of the state, out of the valley of the Kansas river.

SUMMARY.

The analyses of the river water given in tables I–V show a direct variation of solids in suspension, and a direct variation of organic material with the height of the water, and an inverse variation of soluble ingredients with the height of the water.

A comparison of tables I and II shows that the Lawrence sewers have a little effect on the river. This is scarcely observable in the comparative tests we have made, as most of them were made at high stages of the river.

Tables I–V show that very little difference could be observed in samples taken from different places in the river near Lawrence.

A comparison of tables I and V shows that filtration removes a great part of the solids and very much decreases the organic matter.

In tables VI, VII, IX, and X, analyses of water from wells and springs in the city of Lawrence and vicinity show that chlorine cannot be taken as indicating contamination. No chlorine map of the district could be made. The chlorine and solids vary directly with the depth of the wells, and in wells of equal depth increase toward the east. Softest waters and those with least chlorine are found on the hills southwest of the city. Nitrates are sometimes very high in what are apparently pure waters. (See especially table VII.)

Analyses of water from the Lawrence Water Company's system (table VIII) compared with the analyses of the river water (tables I and V), samples taken on the same days, show wide differences in the soluble constituents, thus showing that the water from the wells is very different from river water. In this connection, we especially note that the chlorine in the water company's water, though varying in the analyses made, is much less variable than that in the river water. Abnormal free ammonia in the water taken from the fountain is remarkable and worthy of further investigation.

The few analyses of water from rivers in different parts of the state (table XII) show variations due to the geological formation in their respective localities, and a further study of them promises interesting results.